Pressure cooking

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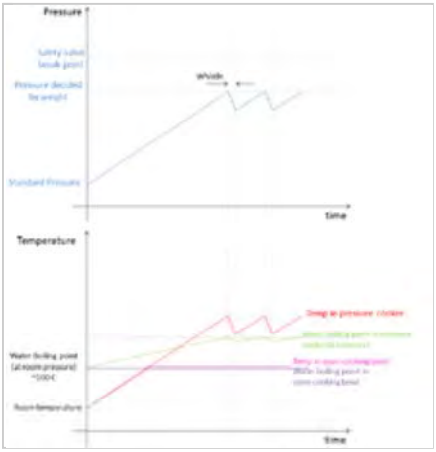
Pressure cooking is the process of cooking food, using water or other cooking liquid, in a sealed vessel, known as a *pressure cooker*. As pressure cooking cooks food faster than conventional cooking methods, it saves energy. Pressure is created by boiling a liquid, such as water or broth, inside the closed pressure cooker. The trapped steam increases the internal pressure and allows the temperature to rise. After use, the pressure is slowly released so that the vessel can be safely opened.

A pressure cooker

Pressure cooking can be used for quick simulation of the effects of long braising. Almost any food which can be cooked in steam or water-based liquids can be cooked in a pressure cooker.



Pressure and temperature in a pressure cooker compared to cooking in an open bowl

Contents

History

In 1679, the French physicist Denis Papin, better known for his studies on steam, invented the *steam digester* in an attempt to reduce the cooking time of food. His airtight cooker used steam pressure to raise the water's boiling point, thus cooking food much more quickly. In 1681, Papin presented his invention to the Royal Society of London, but the Society's members treated his invention as a scientific study. They granted him permission to become a member of the Society afterwards.

A 6 quart pressure cooker manufactured by Archibald Kenrick & Sons in England, circa 1890

In 1864, Georg Gutbrod of Stuttgart began manufacturing pressure cookers made of tinned cast iron.

In 1918, Spain granted a patent for the pressure cooker to Jose Alix Martínez from Zaragoza. Martínez named it the *olla exprés*, literally "express cooking pot", under patent number 71143 in the *Boletín Oficial de la Propiedad Industrial*.[1] In 1924, the first pressure cooking pot recipe book was published, written by José Alix and titled "360 fórmulas de cocina Para guisar con la 'olla expres'",[2] or *360 recipes for cooking with a pressure cooker*.

In 1938, Alfred Vischer presented his invention, the *Flex-Seal Speed Cooker*, in New York City. Vischer's pressure cooker was the first one designed for home use, and its success led to competition among American and European manufacturers.[3] At the 1939 New York World's Fair, National Presto Industries, which was then known as the "National Pressure Cooker Company", introduced its own pressure cooker.

Variants

An *autoclave* is a type of pressure cooker used by laboratories and hospitals to sterilize equipment.

In the food industry, pressure cookers are often referred to as *retorts* or *canning retorts.*

Large pressure cookers are often called *pressure* ***canners*** in the United States, because of their capacity to hold jars used in canning. Pressure canners are specifically designed for home canning, whereas ordinary pressure cookers are not recommended for canning due to the risk of botulism poisoning, because pressure canners hold heat and pressure for much longer than ordinary pressure cookers; these factors are a critical part of the total processing time required to destroy harmful microbes.[4]

Pressure fryers are used for deep fat frying under pressure, because ordinary pressure cookers are not suitable for pressure frying.

Design

Parts

A pressure cooker. The regulator is a weight on a nozzle next to the handle on the lid.

Portable pressure cookers consist of all or most of these basic component parts, depending on the manufacturer and model of pressure cooker:

Pan

- Metal pan body
- Pan handles, usually one each on opposite ends, for carrying the cooker with both hands

Lid

- Lid handle, usually with a locking device button or slider which "clicks" shut and prevents removal while cooking
- Gasket (also known as a "sealing ring") which seals the cooker airtight
- Steam vent with a pressure regulator on top (either a weight or spring device) which maintains the pressure level in the pan
- Pressure indicator pin, for showing the presence or absence of any pressure, however slight
- Safety devices on the lid (typically over-pressure and/or over-temperature pressure release valves)
- Pressure gauge (usually absent but included on some costlier models)

Accessories

- Steamer basket
- Trivet for keeping the steamer basket above liquid
- Metal divider, for separating different foods in the steamer basket e.g. vegetables

Pressure cookers are typically made of aluminum (aluminium) or stainless steel. Aluminum pressure cookers may be stamped, polished, or anodized, but all are unsuitable for the dishwasher. They are cheaper, but the aluminum is reactive to acidic foods, whose flavors are changed in the reactions, and less durable than stainless steel pressure cookers.

Higher-quality stainless steel pressure cookers are made with heavy, three-layer, or copper-clad bottoms (heat spreader) for uniform heating because stainless steel has lower thermal conductivity. Most modern stainless steel cookers are dishwasher safe, although some manufacturers may recommend washing by hand. Some pressure cookers have a non-stick interior.

A gasket or sealing ring, made from either rubber or silicone, forms a gas-tight seal that does not allow air or steam to escape between the lid and pan. Normally, the only way steam can escape is through a regulator on the lid while the cooker is pressurized. If the regulator becomes blocked, a safety valve provides a backup escape route for steam.

To seal the gasket there are several main methods used. Each determines the design of the pressure cooker:

- The **twist-on** design has slots on the lid engaging with flanges on the body, similar to a lid on a glass jar, that works by placing the lid on the pot and twisting it about 30° to lock it in place. A common modern design, it has easily implemented locking features that prevent the removal of the lid while under pressure.
- The **center screw** design has a bar that is slotted in place over the lid and a screw tightened downward to hold the lid on. Though an older design, it is still produced due to its ease of construction and simplicity.
- The **bolt-down** design has flanges on both its lid and its body for bolts to be passed through, and usually uses wingnuts that hinge on the body and so are never fully removed from the cooker; this sealing design is typically used for larger units such as canning retorts and autoclaves. It is very simple to produce, and it can seal with simple and inexpensive gaskets.
- The **internally fitted lid** design employs an oval lid that is placed inside and presses outward; the user inserts the lid at an angle, then turns the lid to align it with the pot opening on top because the lid is larger than the opening. A spring arrangement holds the lid in place until the pressure forms and holds the lid tightly against the body, preventing removal until the pressure is released.

Because of the forces that pressure cookers must withstand, they are usually heavier than conventional pots of similar size.

Capacity

Pressure cookers are available in different capacities for cooking larger or smaller amounts, with 6 litres' capacity being common. The maximum capacity of food is less than the advertised capacity because pressure cookers can only be filled up to 2/3 full, depending on ingredients and liquid (see Safety features section).

Generations

There are three generations of pressure cookers:

First generation

Also known as "old type" pressure cookers, these operate with a weight-modified or "jiggly" valve, which releases pressure during operation.[5] Some people might consider them loud or very loud because the weight-modified valve operates similarly to the piston in a steam engine. They typically offer only one pressure level—with the exception of some newer "old style" pressure cookers that allow the operator to change the weight of the weight-modified valve.

Even today, many of the less expensive modern pressure cookers (such as those manufactured and marketed by Presto) are basically variants on the First Generation cookers, albeit with new safety features, such as a mechanism which prevents the cooker from being opened by any means once it comes to pressure, until it is entirely de-pressurized.

Second generation

These operate with a spring-loaded valve that is often hidden from view in a proprietary mechanism.[5] This generation is characterized by two or more pressure settings. Some of these pressure cookers do not release any steam during operation (non-venting) and instead use a rising indicator with markings to show the pressure level. These only release steam when the pan is opened, or as a safety precaution if the heat source is not reduced enough when the pan reaches the required cooking pressure. Others use a dial that the operator can advance by a few clicks (which alters the spring tension) to change the pressure setting or release pressure;[5] these release steam during operation (venting).

Super cocotte décor SEB, 1973. Aluminium body, polyamide lacquered with an embossed aluminium lid and a stainless steel stirrup. On display at the Musée gallo-romain de Fourvière, Lyon. 18/10.

Third: electric pressure cookers

After the stove-top pressure cookers,[6] in 1991[7] came the electric pressure cookers, called the "third generation" pressure cookers.

These include an electric heat source that is automatically regulated to maintain the operating pressure. They also include a spring-loaded valve (as described above). This pressure cooker type cannot be opened with a cold water quick-release method and should be operated with caution when releasing vapour through the valve, especially while cooking foamy foods and liquids (lentils, beans, grains, milk, gravy, etc.)

Stove top pressure cooker with battery operated timer.

An electric pressure cookers integrates a timer. Depending on cooking control capability, there are three generations of electric pressure cookers:[7][8]

- 1st Generation with mechanical timer. There is no delayed cooking capability.
- 2nd Generation with digital controller. Delayed cooking becomes possible and the controller shows a count-down timer when working pressure is reached.
- 3rd Generation with smart programming. Smart Programming includes pre-set cook times and settings, based on heating intensity, temperature, pressure and duration. Programmable electric pressure cookers have become as intuitive to use as the microwave.[6]

Some cookers are multifunctional (multicookers): pressure cooker, saute/browning, slow cooker, rice cooker, yogurt maker, steamer and stockpot warmer (that can also be used to keep cooked food warm).

Pressure settings

Most pressure cookers have a cooking (operating) pressure setting between 0.8 - 1 bar (11.6 - 15 psi) above sea level pressure (sea level pressure is around 1.016 bar) so the pressure cooker operates at 1.816 to 2.016 bar. The standard cooking pressure of 15 psi above sea level pressure was determined by the United States Department of Agriculture in 1917. At this pressure, water boils at 121 °C (250 °F) (described in vapour pressure of water article).

The higher temperature causes food to cook faster; cooking times can typically be reduced to one-third of the time for conventional cooking methods.[9] The actual cooking time also depends on the pressure release method used after timing *(see Pressure release methods for details)* and the thickness and density of the food, since thicker (and denser) foods take longer to cook. Meat joints and some other foods like sponge puddings and Christmas puddings are typically timed according to their weight. Frozen foods need extra cooking time to allow for thawing.

When pressure cooking at 1 bar/15 psi above sea level pressure, approximate cooking times are one minute for shredded cabbage, seven minutes for boiled potatoes (if cut small, not diced) and three minutes for fresh green beans. If the pressure is released naturally after timing *(see Pressure release methods for details),* cooking times are even shorter. Food cooks more quickly when cut into smaller pieces.

Some recipes may require cooking at lower than 1 bar/15 psi above sea level pressure e.g. fresh vegetables, as these can easily overcook. Many pressure cookers have 2 or more selectable pressure settings or weights.

Non-standard pressure settings

Some pressure cookers have a lower or higher *maximum* pressure than 1 bar/15 psi above sea level pressure or can be adjusted to different pressures for some recipes; cooking times will increase or decrease accordingly. This is typically done by having different regulator weights or different pressure settings. If the recipe is devised for a higher pressure and the pressure cooker does not reach that pressure, the cooking time can be increased slightly to compensate. Electric pressure cookers operate at lower pressures than stovetop pressure cookers.

Operation

Liquid

Pressure cooking always requires liquid. Pressure cooking cannot be used for cooking methods that produce little steam such as roasting, pan frying, or deep frying. However, Kentucky Fried Chicken restaurants use a combination of pressure cooking and frying, with special pressure fryers in which the chicken's own juices supply the water. Cooking time is reduced substantially, to approximately 12 minutes per amount cooked, but the breading texture is much softer (less crispy) than deep-fried chicken since moisture remains in the breading. Thick sauces do not contain enough liquid to vaporize and create pressure, so they usually burn onto the interior base of the pressure cooker after prolonged heating. Sauces should be thickened after pressure cooking.

Bringing to pressure (stove top pressure cookers)

Food is placed inside the pressure cooker with a small amount of water or other liquid such as stock. Food is either cooked in the liquid or above the liquid to be steamed; the latter method prevents the transfer of flavors from the liquid. The lid is closed, the pressure setting is chosen and the pressure cooker is placed on

a stove on the highest heat (less than high for induction cooking to allow air to be vented - see the section below for an explanation). Once the cooker reaches full pressure, the heat is lowered to maintain pressure; timing the recipe begins at this point. Recipes for foods using raising agents such as steamed puddings call for gentle pre-steaming, without pressure, in order to activate the raising agents prior to cooking and achieve a light, fluffy texture.

It takes several minutes for the pressure cooker to reach the selected pressure level. It can take around 10 minutes or longer depending on: the quantity of food, the temperature of the food (cold or frozen food delays pressurization), the amount of liquid, the power of the heat source and the size of the pressure cooker.

A common mistake is for the user to start timing when a colored pop-up indicator rises, which happens when there is the slightest increase in pressure, instead of waiting for the cooker to reach its selected pressure level. The typical pop-up indicator only shows that the cooker has pressure inside, which does not reliably signal that the cooker has reached the selected pressure. This pop-up indicator often acts as an interlock, preventing the lid from being opened while there is internal pressure. Manufacturers may use their own terminology for it, such as calling it a *"locking indicator."*

As the internal temperature rises, the pressure also rises until it reaches the design gauge pressure. Timing the recipe begins when the selected pressure is reached. With first generation designs, the pressure regulator weight begins levitating above its nozzle, allowing excess steam to escape. In second generation pressure cookers, either a relief valve subsequently opens, releasing steam to prevent the pressure from rising any further or a rod rises with markers to indicate the pressure level, without constantly venting steam. At this stage, the heat source should be reduced to the lowest possible heat that still maintains pressure, as extra heat wastes energy and increases liquid loss.[9]

Removal of air

Before the pressure cooker lid is sealed airtight, the internal air has to be mostly replaced by steam. Steam has a much higher specific heat than air, and the presence of steam rather than air inside the pressure cooker is how it's able to transfer sufficient heat into the parts of the food that aren't submerged in liquid, such as a pot roast. If the lid is sealed before enough air has been removed, not enough heat can be transferred to the food, and food may be undercooked; the presence of air would make the food cook more like it's in an oven than a pressure cooker. To remove the air, steam is vented for several minutes to replace the volume of air inside the cooker. This is why a pressure cooker takes about 10 minutes to reach pressure. For pressure cookers with a weight, the weight is placed over the steam vent pipe while steam is being emitted, to ensure the air inside has escaped. The newer generation pressure cookers, which have no weights, automatically expel air from inside for several minutes before a coloured pop-up indicator pin rises to seal the lid airtight; pressure then builds in the now airtight cooker. If the pressure cooker is already hot or a stovetop pressure cooker is placed on a very strong heat source - such as induction on too high a setting, the lid can seal airtight too quickly before the air inside has been removed. In these situations, a slightly lower heat setting can be used to allow the water to boil slower in order to vent the air.

Food containers

Small containers such as plastic pudding containers, can be used in a pressure cooker, provided that the containers (and any covering used) can withstand temperatures of 130 °C (266 °F) and are not placed directly on the interior base. The containers can be used for cooking foods that are prone to burning on the

base of the pressure cooker. A lid for the container may be used, provided that the lid allows some steam to come into contact with the food and the lid is securely fitted; an example is foil or greaseproof paper, pleated in the center and tied securely with string. Containers that are cracked or have otherwise sustained damage are not suitable. Cooking time is longer when using covered containers because the food is not in direct contact with the steam. Since non-metal containers are poorer heat conductors, the type of container material stated in the recipe cannot be substituted without affecting the outcome. For example, if the recipe time is calculated using a stainless steel container and a plastic container is used instead, the recipe will be undercooked, unless the cooking time is increased. Containers with thicker sides, e.g., oven-proof glass or ceramic containers, which are slower to conduct heat, will add about 10 minutes to the cooking time. Liquid can be added inside the container when pressure cooking foods such as rice, which need to absorb liquid in order to cook properly.

Pre-frying ingredients

The flavor of some foods, such as meat and onions, can be improved by gently cooking with a little pre-heated cooking oil, butter or other fat in the open pressure cooker[9] over medium heat (unless the manufacturer advises against this) before pressure cooking. It is important both not to overheat the empty pressure cooker and never to heat the empty cooker with the lid and gasket in place. Overheating can cause warping and other damage. The pressure cooker needs to cool briefly before adding liquid;[9] otherwise some of the liquid will evaporate instantly, possibly leaving insufficient liquid for the entire pressure cooking time; if deglazing the pan, this has to be taken into account.

Pressure release methods

After cooking, there are three ways of releasing the pressure, either quickly or slowly, before the lid can be opened. Recipes for pressure cookers state which release method is required at the end of the cooking time for proper results. Failure to follow the recommendation may result in food that is under-cooked or over-cooked. Only one of these release methods is used after timing, as recommended in the recipe.

To avoid opening the pressure cooker too often while cooking different vegetables with varying cooking times, the vegetables that take longer to cook can be cut into smaller pieces and vegetables that cook faster can be cut into thicker pieces.[9]

Manual, normal, regular, or automatic release

This method is sometimes called a *quick release,* not to be confused with the cold water release (mentioned below). It involves the quick release of vapor by gradually lifting (or removing) the valve, pushing a button, or turning a dial. It is most suitable to interrupt cooking to add food that cooks faster than what is already in the cooker. For example, since meat takes longer to cook than vegetables, it is necessary to add vegetables to stew later so that it will cook only for the last few minutes. Unlike the cold water release method, this release method does not cool down the pressure cooker. The user must release the steam with caution to avoid being scalded. This release method is not suitable for foods that foam and froth while cooking; the hot contents might spray outwards due to the pressure released from the steam vent. This release method takes about two minutes to release the pressure before the lid can be opened.

Natural release

The natural release method allows the pressure to drop slowly; this is achieved by removing the pressure cooker from the heat source and allowing the pressure to lower without action. It takes approximately 10 to 15 minutes (possibly longer) for the pressure to disappear before the lid can be opened. On many pressure cookers, a coloured indicator pin will drop when the pressure has gone. This natural release method is recommended for foods that foam and froth during cooking, such as rice, legumes, or recipes with raising agents such as steamed puddings. The texture and tenderness of meat cooked in a pressure cooker can be improved by using the natural release method.[9] The natural release method finishes cooking foods or recipes that have longer cooking times because the inside of the pressure cooker stays hot. This method is not recommended for foods that require very short cooking times, otherwise the food overcooks.

Cold water quick release

This method is the fastest way of releasing pressure with portable pressure cookers, but can be dangerous if performed incorrectly. It is therefore safer to release pressure by following the other methods. It is recommended to read the manufacturer's instruction book, as some may advise against the cold water release or require it to be performed differently.

The cold water release method involves using slow running cold tap water, over the edge of the pressure cooker lid, being careful to avoid the steam vent or any other valves or outlets and never immersing the pressure cooker under water, otherwise steam can be ejected from under the lid, which could cause scalding injury to the user; also the pressure cooker lid can be permanently damaged by an internal vacuum if water gets sucked into the pressure cooker, since the incoming water blocks the inrush of air.

The cold water release is most suitable for foods with short cooking times. It takes about 20 seconds for the cooker to cool down enough to lower the pressure so that it can be safely opened. This method is not suitable for electric pressure cookers, as they are not "immersible."

The cold water release method is not recommended when cooking pulses e.g. red kidney beans, as the sudden release of pressure can cause the bean to burst its skin.

Advantages

Foods cook much faster with pressure cooking than with other methods (except for small quantities in microwave ovens). Pressure cooking requires much less water than conventional boiling, so food can be ready sooner. Less energy is required than that of boiling, steaming, or oven cooking. Since less water or liquid has to be heated, the food reaches its cooking temperature faster. Using more liquid than necessary wastes energy because it takes longer to heat up; the liquid quantity is stated in the recipe. Pressure cookers can use much less liquid than the amount required for boiling or steaming in an ordinary saucepan. It is not necessary to immerse food in water. The minimum quantity of water or liquid used in the recipe to keep the pressure cooker filled with steam is sufficient. Because of this, vitamins and minerals are not leached (dissolved) away by water, as they would be if food were boiled in large amounts of water. Due to the shorter cooking time, vitamins are preserved relatively well during pressure cooking.[10]

Several foods can be cooked together in the pressure cooker, either for the same amount of time or added later for different times.[9] Manufacturers provide steamer baskets to allow more foods to be cooked together inside the pressure cooker.

Food is cooked at a temperature above the normal boiling point of water, killing most micro-organisms. A pressure cooker can be used as an effective sterilizer for jam pots, glass baby bottles, or for water while camping.

The pressure cooker speeds cooking considerably at high altitudes, where the lower atmospheric pressure reduces the boiling point of water. Lower water temperature reduces water's effectiveness for cooking or preparing hot drinks. The increased temperatures due to pressure cooking are also used to promote the Maillard reaction to develop more desirable flavor profiles that would not be obtainable using temperatures typical of boiling. The flavours are more concentrated in the higher temperature and sealed environment of the pressure cooker, so less seasoning is required.[9]

An ideal pressure cooker contributes to the hygiene of the kitchen[11] as well. Modern pressure cookers do a lot more than just cooking foods. This cookware reduces cook's dependency on multiple cooking tools for meals. Thus, the kitchens are less messy and easy to clean and maintain.

Disadvantages

Pressure cookers are considerably more expensive than conventional saucepans of the same size. The additional gasket (sealing ring) requires special care when cleaning (e.g., not washed with kitchen knives), unlike a standard lid for a saucepan. Food debris must be cleaned from the gasket after every use. The gasket/sealing ring needs replacing with a new one about once a year (or sooner if it is damaged e.g. a small split). A very dry gasket can make it difficult or impossible to close the lid, however smearing the gasket sparingly with vegetable oil alleviates this problem (using too much vegetable oil can make the gasket swell and prevent it sealing properly). A gasket which has lost its flexibility makes bringing the cooker up to pressure difficult as steam can escape before sufficient pressure is generated to provide an adequate seal; this is usually a sign that the gasket needs replacing with a new one. Oiling the gasket with vegetable oil may alleviate the problem temporarily, but a new gasket is often required. Pressure cooker manufacturers sell replacement gaskets and recommend their replacement at regular intervals e.g. annually. If the pressure cooker has not been used for a long time, the gasket and other rubber or silicone parts will dry out and will likely need replacing.

In order to inspect the food, the pressure cooker needs to be opened, which halts the cooking process. With a conventional saucepan, this can be done in a matter of seconds by visually inspecting the food. As a result, accurate timing is essential for the recipe e.g. with an audible timer.

The increased weight of conventional pressure cookers makes them unsuitable for applications in which saving weight is a priority, such as camping. However, small, lightweight pressure cookers are available for mountain climbers *(see Use at high altitudes)*.

A minimum quantity of liquid is required to create and maintain pressure, as indicated in the manufacturer's instruction manual. More liquid is required for longer cooking times. This is not desirable for food requiring much less liquid, but recipes and books for pressure cookers take this into account.

Safety features

Early pressure cookers equipped with only a primary safety valve risked explosion from food blocking the release valve. On modern pressure cookers, food residues blocking the steam vent or the liquid boiling dry will trigger additional safety devices. Modern pressure cookers sold from reputable manufacturers have

sufficient safety features to prevent the pressure cooker itself from exploding. When excess pressure is released by a safety mechanism, debris of food being cooked may also be ejected with the steam—which is loud and forceful. This can be avoided if the pressure cooker is regularly cleaned and maintained in accordance with the manufacturer's instructions and never overfilled with food and/or liquid: a pressure cooker should never be filled more than two-thirds full with solid food, half full for liquids and foods that foam and froth (e.g., rice, pasta), and no more than one-third full for pulses (e.g., lentils).[12] Adding a tablespoon of cooking oil minimises foaming.[13]

Modern pressure cookers typically have two or three redundant safety valves and additional safety features, such as an interlock lid that prevents the user from opening the lid when the internal pressure exceeds atmospheric pressure, preventing accidents from a sudden release of hot liquid, steam and food. If safety mechanisms are not correctly in place, the cooker will not pressurize the contents. Pressure cookers should be operated only after reading the instruction manual, to ensure correct usage. Pressure cooker failure is dangerous: a large quantity of scalding steam and water will be forcefully ejected and if the lid separates it may be propelled with considerable force. Some cookers with an internally fitted lid may be particularly dangerous upon failure as the lid fits tighter with increasing pressure, preventing the lid from deforming and venting around the edges. Due to these dangers pressure cookers are generally over-engineered in a safety regard and some countries even have regulations to prevent the sale of non-compliant cookers.

For first generation pressure cookers with a weighted valve or "jiggler", the primary safety valve or regulator is usually a weighted stopper, commonly called "the rocker" or "vent weight". This weighted stopper is lifted by the steam pressure, allowing excess pressure to be released. There is a backup pressure release mechanism that releases pressure quickly if the primary pressure release mechanism fails (e.g., food jams the steam discharge path). One such method is a hole in the lid that is blocked by a low melting point alloy plug and another is a rubber grommet with a metal insert at the center. At a sufficiently high pressure, the grommet will distort and the insert will blow out of its mounting hole to release pressure. If the pressure continues to increase, the grommet itself will blow out to release pressure. These safety devices usually require replacement when activated by excess pressure. Newer pressure cookers may have a self-resettable spring device, fixed onto the lid, that releases excess pressure.

On second generation pressure cookers, a common safety feature is the gasket, which expands to release excess pressure downward between the lid and the pot. This release of excess pressure is forceful and sufficient to extinguish the flame of a gas stove.

Pressure cookers sold in the European Union (EU) must comply with the Pressure Equipment Directive.[14]

Use at high altitudes

A pressure cooker can be used to compensate for lower atmospheric pressure at high elevations. The boiling point of water drops by approximately 1 °C per every 294 metres of altitude (1 °F per every 540 feet (160 m) of altitude),[15] causing the boiling point of water to be significantly below the 100 °C (212 °F) at standard pressure. Without the use of a pressure cooker, boiled foods may be undercooked, as described in Charles Darwin's *The Voyage of the Beagle* (chapter XV, March 20, 1835):

> Having crossed the Peuquenes [Piuquenes], we descended into a mountainous country, intermediate between the two main ranges, and then took up our quarters for the night. We were now in the republic of Mendoza. The elevation was probably not under 11,000 feet

> (3,400 m) [...]. At the place where we slept water necessarily boiled, from the diminished pressure of the atmosphere, at a lower temperature than it does in a less lofty country; the case being the converse of that of a Papin's digester. Hence the potatoes, after remaining for some hours in the boiling water, were nearly as hard as ever. The pot was left on the fire all night, and next morning it was boiled again, but yet the potatoes were not cooked.

At higher altitudes, the boiling point of liquid in the pressure cooker will be slightly lower than it would be at sea level. When pressure cooking at high altitudes, cooking times need to be increased by approximately 5% for every 300 m (980 ft) above 610 m (2,000 ft) elevation. The absolute pressure in a pressure cooker will always be lower at higher altitudes, since the differential pressure remains the same (if one were to travel high enough the pressure within the cooker would drop below sea-level pressure). Since weight is one of the major concerns, mountaineering pressure cookers may be designed to operate at a much lower differential pressure than regular units so that thinner, lighter construction can be used. Generally, the objective is raising the cooking temperature to make cooking possible where it would otherwise be completely impractical and to conserve fuel by reducing heat lost through boiling.

Lightweight pressure cookers as small as 1.5 litres (0.40 US gal) weighing 1.28 kilograms (2.8 lb) are available for mountain climbers. Sherpas often use pressure cookers in base camp.

Science of pressure cooking

In an ordinary, non-pressurized, cooking vessel, the boiling point of water is 100 °C (212 °F) at standard pressure; the temperature of food is limited by the boiling point of water because excess heat causes boiling water to vaporize into steam. In a sealed pressure cooker, the boiling point of water increases as the pressure rises, resulting in superheated water. At a pressure of 1 bar or ~15 psi (pounds per square inch) above the existing atmospheric pressure, water in a pressure cooker can reach a temperature of up to 121 °C (250 °F), depending on altitude. The boiling temperature of water (and water-based liquids) is determined by the ambient atmospheric pressure. Pressure cookers always require liquid in order to cook food under pressure. At sea level, the boiling temperature of water is 100 °C (212 °F) and excess heat only increases the rate at which water evaporates into steam vapour; more heat does not increase the temperature of the water. At higher altitudes above sea level, the atmospheric pressure is lower and thus the boiling temperature of water is lower, because the lower atmospheric pressure pushing on the water makes it easier for the water molecules to escape the surface compared to higher atmospheric pressure.[16] Inside a pressure cooker, once the water (liquid) is boiling and the steam is trapped, the pressure from the trapped steam increases and this pushes on the liquid, which increases its boiling temperature, because it becomes harder for the water molecules to escape from the surface as the pressure increases on it.[16] The heat applied to the liquid by the heat source continues to create more steam pressure and the extra heat also raises the temperature of the liquid under this increased pressure. Both the liquid and steam are at the same temperature. Once the selected pressure level is reached, the pressure regulator on the lid indicates this and now the heat source can be lowered to maintain that pressure level and save energy, since extra heat will not increase the temperature of the liquid if the pressure is not allowed to rise—excess pressure will only escape as fast-flowing steam from the lid.

As a general rule, increasing the temperature of many everyday chemical reactions by 10 deg. C doubles the rate of reaction, halving the time for completion. Thus a pressure cooker that can attain temperatures around 120 °C (248 °F) can complete cooking in a quarter of the time that it would take using ordinary boiling.

In addition, because of a much higher heat capacity, steam and liquids transfer heat more rapidly than dry air. As an example, the hot *air* inside an oven at, say 200 °C (392 °F), will not immediately burn your skin, but the wet steam from a boiling kettle at 100 °C (212 °F) will scald skin almost instantly and 'feel' hotter, despite the steam (and water) in the kettle being at a lower temperature than the air inside a hot oven. Thus the internal temperature of material in a pressure cooker will rise to the desired value much more quickly than if it were in a hot oven.

However, some reactions such as the Maillard reaction that produces "browning" and associated flavors during roasting or frying, require temperatures higher than are found in a pressure cooker. Pre-frying ingredients e.g. meat in the open pressure cooker can achieve the Maillard reaction.

Use in food detoxification

Some food toxins can be reduced by pressure cooking. A Korean study of aflatoxins in rice (associated with *Aspergillus* fungus) showed that pressure cooking was capable of reducing aflatoxin concentrations to 12 –22% of the amount in the uncooked rice.[17] Pressure cookers are *not* guaranteed to destroy all harmful microorganisms in food, especially when used for short periods of time.[4]

Foods unsuitable for pressure cooking

Some foods are not recommended for pressure cooking. Foods such as macaroni, cranberries, cereals and oatmeal could expand too much, froth, and sputter, which can block the steam vent.[12]

Use as an autoclave

Pressure cookers have been used effectively as makeshift medical autoclaves in rural countries where there is no electrical infrastructure and where the cost of such a piece of equipment would otherwise be prohibitive. Although working on the same principle there are several operational differences such as professional autoclaves having purging ability to remove air before sterilization and having programmable control over the sterilization cycle. Education on usage is very important as the sterilization cycle is often much longer due to the presence of air in the cooker and most pressure cookers require modification to reach sufficient sterilization temperature which although within the capabilities of most pressure cookers, is still risky. Autoclaves are very important in poor countries since they rely on re-usable medical equipment and many places re-use hypodermic needles.

Use in terrorism

The appliance has been adapted as a crude type of bomb, which has been used in terrorist attacks.[18]

- 2006 Mumbai train bombings
- 2010 Stockholm bombings (failed to explode)
- 2010 Times Square car bombing attempt (failed to explode)
- 2013 Boston Marathon bombing
- 2016 New York and New Jersey bombings

See also

- Cooker
- Food processor
- List of cooking appliances
- Multicooker
- Pressure frying
- Rice cooker, many employ pressure cooking
- Slow cooker or Crock-Pot
- Stove top

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External links

Wikimedia Commons has media related to ***Pressure cookers***.

Wikibooks Cookbook has a recipe/module on

- Science of Pressure Cooking (http://www.edinformatics.com/math_science/science_of_cooking/science_of_pressure_cooking.htm)

Pressure cooking

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